DESIGN IMPROVEMENT OF COFFEE MAKER USING DESIGN FOR ASSEMBLY (DFA) METHOD

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ABSTRACT

Nowadays companies especially manufacturer trying to cut down the manufacturing cost by improved and adjusted the manufacturing process and assembly method and at the same time increase their profit. In order to be a competent player in the market, the product should arrive into market within a short time and reasonable price. This study basically shows a detailed study to improve the design of Coffee Maker by using Design for Assembly and also studies the assembly efficiency using Boothroyd Dewhurst Design for Assembly (DFA) method. Assembly cost is one of the major operations in manufacturing but always ignored during designing stage. In this study, comparative analysis was done between current and alternative design. The design was done by using CATIA software and analysed by using manual and DFA software analysis to get the efficiency of current design. By applying Boothroyd Dewhurst DFA method guideline, alternative design was generated and analysed using the same method to compare the effectiveness of this new alternative design focuses on part that has been identified for improvement. From the result, it was found that the assembly cost was decreased from 117.49 second into 92.59 second after reduction from 14 parts into 11 parts. It was proven that this Boothroyd Dewhurst DFA method was able to improve the design in terms of design efficiency where the current design efficiency is 5.1% and for proposed design the efficiency became 6.3%. This method can be applied in manufacturing company in order to improve their design effectiveness.

ABSTRACT

Kebanyakan syarikat terutama di dalam bidang pembuatan sebenarnya mencuba untuk menambah baik and mengubah kaedah bagi proses pembuatan yang lebih baik dan pada masa yang sama juga cuba untuk mencapai keuntungan. Dalam usaha untuk menjadi saingan di dalam pasaran, produk sebenarnya haruslah sampai di dalam pasaran dalam jangka masa yang singkat dan pada harga yang berpatutan dalam usaha untuk mencapai keuntungan dan seterusnya mengekalkan kepuasan pelanggan, Projek ini sebenarnya menunjukkan cara yang lebih mendalam menggunakan konsep reka bentuk untuk pemasangan mesin pembancuh kopi dan ianya menjurus kepada kaedah Boothroyd dan Dewhurst di mana kaedah ini meluas di gunakan di dalam industri reka bentuk di peringkat awal proses membangunkan produk. Kos pemasangan sebenarnya memberikan impak maksimum kepada syarikat pembuatan khususnya dan ianya selalu tidak di berikan perhatian dan pandanagn serius. Di dalam projek ini, proses pembandingan antara di antara reka bentuk ataupun konsep sedia ada dengan reka bentuk yang di cadangkan telah di lakukan menggunakan perisian CATIA untuk membantu membangunkan reka bentuk dan seterusnya menganalisa produk untuk mendapatkan effiensi pemasangan. Dengan menggunakan kaedah Boothroyd dan Dewhurst ini reka bentuk yang di ketengahkan telah di hasilan dan di analisa sama seperti sebelum untuk mendapatkan effisiensi pemasangan dan menbandingkan dengan reka bentuk sedia ada. Berdasarkan analisa di dapati masa pemasangan telah menurun daripada 120.94 saat kepada 97.03 saat selepas mengurangkan bilangan kompenan daripada 14 kepada 11 komponen. Selain itu di dapati juga effisiensi bertambah daripada 5.1% bagi reka bentuk asal kepada 6.3% bagi reka bentuk yang di cadangkan. Boleh di katakan juga kaedah ini memberi kesan yang cukup bagus kepada syarikat pemasangan bagi untuk meningkatkan keuntungan dengan mengurangkan kos pemasangan dan kos pekerja.

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CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Nowadays industrial production is under great pressure due to market globalisation to shorten life of products of increase product diversity for greater demand of the clients on quality and shorter delivery times. The last 20 years have seen a major change in the design and operation of consumer products especially in term of home appliance such as washing machine, rice cooker and water heater as well as the introduction of new products such as compact disc players (Selvaraj *et al*.,2009). Consumer product plays an important role in human life. Consumer product can be describe as an item of common or daily use, ordinarily bought by individuals or households for private consumption.

1.2 PROJECT SYNOPSIS

New Product Development is a complex and creative process, which is inherently difficult to manage and improve. Developing successful product requires the ability to predict, early in the product development process, the life cycle impact of design decisions. The term DFMA is defined as a set of guidelines developed to ensure that a product is designed so that it can be easily and efficiently manufacture and assemble with a minimum labour effort, assemble time, and cost to manufacture the product. During a product development, DFA method ensures that the transition from the design phase to the production phase is smooth and rapid as possible.

1.3 PROBLEMS STATEMENT

In manufacturing processes it is encompassed of a large number of distinct processes which all influence product and assembly cost and also product quality. Other than that, mostly lot of product nowadays consist of unnecessary features and joining for instance. This problem will cause a company major losses in their business. Assembly costs play a significant role in overall production cost (Boothroyd *et al*,. 1994), estimates that they often account for more than half of all the direct cost involved in manufacturing. Design for assembly here as a benchmarking tool to study competitor's products, our product's quality and assembly difficulties. Therefore, this project would focus on Coffee Maker (Figure 1.1) as a consumer product which would through Boothroyd & Dewhurst method.

Figure 1.1: Coffee Maker

1.4 PROJECT OBJECTIVES

The purpose of this study basically required students to apply the concept of product simplification and cost reduction. Hence, objective of this project are;

i. To analyse the current design of selected Coffee Maker.
ii. To reduce assembly cost by part reduction.
iii. To validate the design and assembly efficiency of the product using Boothroyd-Dewhurst method.

1.5 SCOPE OF STUDY

In order to finish this project require precise scope of work and proper plan need to be followed before it would achieve it objective. The scopes of study are;

i. Initial study about the effect toward cost and time.
ii. Redesign the Coffee Maker Machine from feasibility study.
iii. Validate the particular product through Design for Assembly software.
iv. Redesign the particular product through Design for Assembly software.

1.6 PROJECT SCHEDULE

According to the gant chart in appendices A, it is clearly shows that the project basically start on week 1 whereby the literature review and software exposure took placed. Literature review is a way to study the knowledge related to design for assembly (DFA) then the information about past concept and current design about coffee maker, design for assembly and Boothroyd-Dewhurst method using many way such as from internet, journal, and book and classmate opinion. With this it seems that we have foundation to start project because we have some knowledge about it.

In week 2, the coffee maker had been disassembled and being assembles back manually in order to determine the difficulty and initial assembly time. From that we could identified where is the part that need to improve in week 3 until week 5. This stage quite crucial because this improvement design would determine the simplification of Coffee maker that been selected. After that, it would easy for us to redesign the part that being identified by using CATIA software by considering the manufacturing processes and the design. This stage took placed started in week 5 until week 8.

After completed identified and redesign the part, it is necessary for us to analyzed the new design by using Design for Assembly (DFA) software. Before that the current design must through this software so that the comparison between new design and old design could be table out this stage basically planned until week 10. Then the results are analyzed and figure out from DFMA software.

The thesis writing takes about seven week to complete started from week 7 until week 14 including all information about this entire project. In this thesis also include literature review, methodology and result from this project. Final presentation would take place in week 14 after final draft thesis being submitted to the supervisor.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

A rational design for easy and low cost assembly is the selection of the most appropriate method for assembling these products. Basically 70 to 80 percent of the cost of manufacturing a product is determined during the design phase (Boothroyd *et al*., 1994). So, a design Engineer should be concerned with the ease and cost of assembly. Thus, the concept of design for assembly (DFA) emerged.

2.2 PRODUCTS AND INDUSTRIAL DESIGN

In general, the product is defined as a thing produced by labour or effort. In manufacturing, products are purchased as raw materials and sold as finished goods. The products are things sold to consumers by enterprises. Design refers to the orderly and organized technical modelling activity conducted for certain purposes (Wang *et al*., 2010). Industrial designers need to take into account many factors when deciding the applicability of product design, including quality of user interface, maintenance and repair, rational use of resources, product differentiation and so on.

2.3 DESIGNS FOR ASSEMBLY

Design for Assembly (DFA) is an approach to reduce the cost of the product and time of assembly by simplifying the product and process. The DFA method should be considered at all stages of the design process especially in the early stages

(Boothroyd *et al*., 1994). In this project, type of assembly that must be considered is manual assembly.

Design for Assembly (DFA) can be say as the systematic analysis process primarily intended to reduce the assembly costs of a product by simplifying the product design. (Tatikonda *et al*., 1994). It does so by first reducing the number of parts in product design and then by ensuring that remaining parts are easily assembled.

Design for Assembly (DFA) roughly calculates expected unit material and labour assembly cost and also find an efficiency rating which is relative measure of products ease of assembly (Dewhurst *et al*., 1987). From this point of view, these product cost and efficiency figures can be used to evaluate alternative design and assembly approaches early in a new product development effort.

There are two uses of DFA. It may used to redesign a product already in manufacture or product being remarketed or reversed engineered (Tatikonda *et al*., 1994). Beside that DFA may also used for analysis of a product while it is in design. Some manufacture or company choose to apply the analysis later in design stage or others may in early stage. DFA technique can be applied manually or with software and both approaches lead to simpler product structure and assembly system (Kirkland *et al*., 1998).

There are several methods that widely use in industry to achieve Design for Assembly (DFA). The most widely used in industry nowadays is Boothroyd Dewhurst method, Hitachi Assembly Evaluation Method and Lucas Hull method. However, in this project is only focus on Design for Assembly using Boothroyd & Dewhurst method.

2.3.1 Preparing for DFA Analysis

First of all training in the technique of DFA rules and software is required and generally can be completed in a day. DFA cannot tell the designer exactly what to do to achieve improvements and designer must still be creative in determining alternative approaches that might solve or reduce problems.

Data requirement is crucial in DFA analysis. Data requires a substantial amount of data on the exact nature of the individual parts in subassembly, material used and tolerances. Further more the details assembly information on the types of assembly motions, task time and labour and equipment costs are also required (Walter *et al*., 1989). Some of this data can be found in DFA handbooks in traditional manufacturing and industrial engineering books and tables. Costs and efficiency scores cannot be determined unless data is completed.

DFA costing and efficiency scoring is tabulated manually on evaluation or via computer software evaluation support using simple algorithm (Tatikonda *et al*., 1994). For given design each assembly step is broken down into time and motion primitive such as part orientation, feeding and insertion time and motions (Boothroyd *et al*., 1994).

In the next stage of analysis, the DFA team or who ever deal with it redesign the product following a number of design rules:

I. Avoid projections and holes lead to tangling.
II. Make part symmetrical to avoid extra orientation efforts.
III. If symmetrical cannot be achieved provide asymmetrical features that be used for orientation.

2.3.2 Boothroyd & Dewhurst Method

This technique is a systematic way to achieve cost reduction through reducing the number of parts to be assembled and then ensuring that the remaining parts are easy to assemble.The analysis cannot be employed to create a design from nothing but rather is used to evaluate and refine an existing design.

The Boothroyd and Dewhurst DFA analysis is basically completed in 6 steps. The flow chart of Boothroyd and Dewhurst DFA analysis is show in Figure 2.1

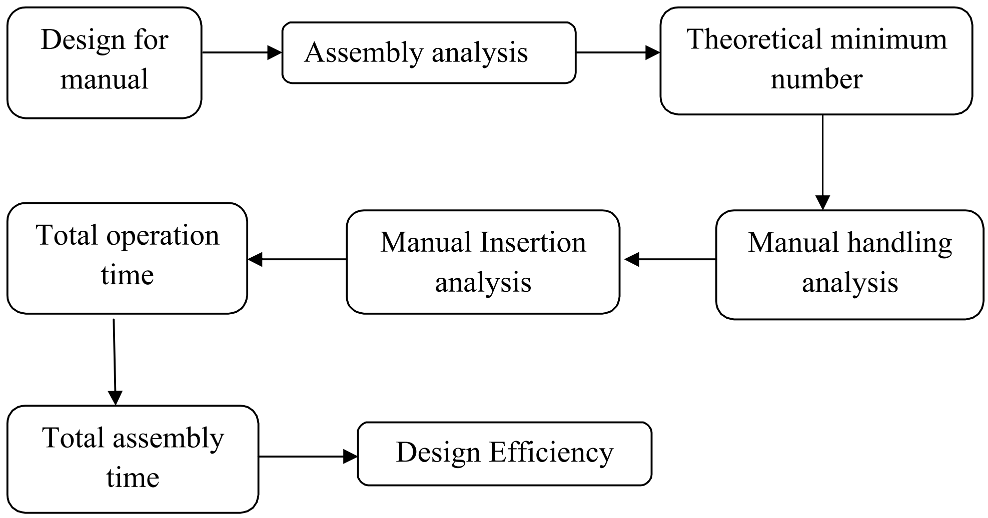

Figure 2.1: Boothroyd Dewhurst DFA analysis

(Source: Boothroyd *et al*., 1994)

2.4 CASE STUDY 1: GREAT DESIGN HINGES ON DFMA (Source: Retrieved from http://www.dfma.com/resources/southco.htm)

2.4.1 Company and Situation

Now we look at another simple case study related to Design for Assembly (DFA) application. Southco Inc. manufactures latches, hinges, fasteners, inject/eject mechanisms and other access hardware for enclosures and cabinets. Over thirty percent of their business is custom work. New customer requested a quotation for a replacement hinge on their enclosure. The customer was looking for a load bearing counterbalance hinge of the type used to control the vertical opening and closing of heavy lids. The hinge currently in use was sent to Southco for evaluation so that they could propose a custom design and provide costing data.

The initial review determined that Southco's manufacturing cost was almost the same as the customer's targeted sell price for the hinge, leaving no profit margin to speak.

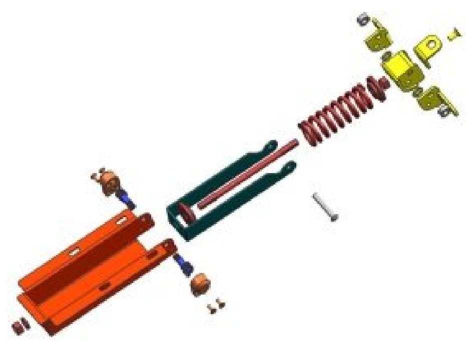

Figure 2.2: Preliminary design
(Source: Retrieved from http://www.dfma.com/resources/southco.htm)

By using DFMA, the product development team was able to dramatically reduce assembly times and costs and eliminate several manufacturing operations so that Southco could make the hinge profitably while still meeting the customer's requirements.

2.4.2 DFA Analysis

DFA quantitatively evaluates both part designs and the overall assembly, helping engineers to identify unnecessary parts as they determine assembly times and costs. It also offers strategies for eliminating parts. The outcome of a DFA analysis is a simpler, more elegant product that is both functionally efficient and easy to assemble.

For its analysis, the team at Southco relied on the Design for Assembly methodology and database, which documents part handling and insertion times and also assigns codes that indicate handling and insertion methods. One of the lessons learned from the DFA analysis was how fasteners like nuts and bolts add significant assembly time which is for example, orienting the nut on the bolt, picking up the driver, driving the nut, and putting down the driver.

The redesigned counterbalance hinge (Figure 2.3) is now in full at the Southco Honeoye Falls Facility. It fulfils all the requirements proposed by the customer, is quieter in operation, and bears higher loads as well.

Figure 2.3: Redesign Concept
(Source: Retrieved from http://www.dfma.com/resources/southco.htm)

2.4.3 Cutting Costs

It can see at this point the new hinge more than met its costing goals. Total component count went from 45 to 30 pieces. Total assembly operations dropped from 14 to 5. The overall cost of the hinge was reduced by 53 percent, profits increased to a level that made it possible to market the hinge at an attractive price.With results like that, DFMA is on its way to becoming a standard design methodology at Southco.

2.5 A SHORT CASE STUDY 2: REDESIGN OF FORKLIFT HYDRAULIC CYLINDER

(Source:Retrievedfromhttp://www.dfma.com/resources/raymond.htm)

2.5.1 Company and Situation

The Raymond Corporation was introduced to Boothroyd Dewhurst Design for Manufacturing and Assembly cost reduction software in 2006. Raymond is part of the Toyota Materials Handling Group, which is the largest lift truck manufacturer in the world. This study will detail how the Boothroyd Dewhurst DFMA software was used to assist in the part count reduction of the Model 7400 Reach-Fork truck.

From figure 2.4 shows there are two sets of hydraulic cylinders installed in the elevating section of this truck that provide the lifting mechanism to the forks. They are referred to as the “main lift” cylinders and the “free lift” cylinders. Part counts were reduced for both sets of cylinders but more focus was applied to the free lift cylinders due to the intricacy of the design.

At the full extension of the free lift cylinder, the hydraulic system starts extending the main lift cylinders. The term used to describe this event is called “staging.” The first step was to examine the current staging cylinder design and brainstorm ideas as to how to reduce part count of the patented cylinder without losing any cushioning or having an increase in noise during staging.

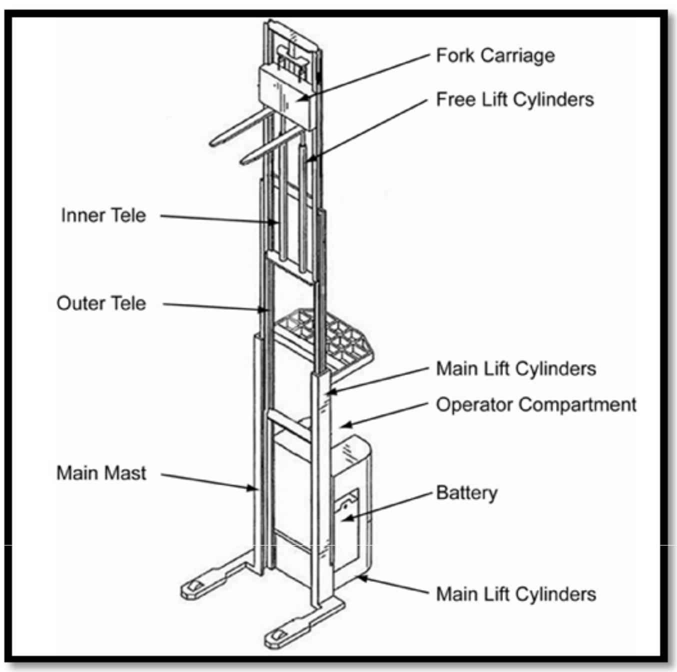

Figure 2.4: Model 7400 Reach-Fork truck

(Source: Retrieved from http://www.dfma.com/resources/raymond.htm)

2.5.2 DFA Analysis

The analysis of the staging cylinders started with determining a baseline cost using the DFMA software. From there, the new design was analysed for cost to compare with the baseline cost. The promising results led to building prototype versions of the redesigned staging cylinders.

The new design saw a traditional two part design reduced to one part. A combination end cap/manifold eliminated welding the existing manifold to the tubing side. The top end cap also changed and went from being retained by a snap ring to becoming a screw on end cap. This also reduced machining to the tubing and made for an easier removal of the end cap for seal replacement. The free life chain anchors were also reduced from a right and a left hand part to a common one used on both right and left free lift cylinders. Lowering the chain anchor also allowed manufacturing to weld the anchor in a different order in the assembly process that reduced assembly time.

The lower portion of each cylinder, main and free lift, acts as a cushion as well when the cylinders retract and collapse the mast. Using common parts increased annual part quantities used and lowered part cost in some cases.

2.5.3 Result

The hydraulic cylinder assemblies were analysed with the Design for Assembly (DFA) software. Table 2.1 shows the comparison of the old and new free lift staging cylinders. These analyses quickly showed that the new designs would lower assembly part count and allowed Raymond Purchasing to use the DFM results when procuring the new parts.

Table 2.1: Comparison of the old and new free lift staging cylinders.
(Source: Retrieved from http://www.dfma.com/resources/raymond.htm)

	Existing Free Lift Cylinder	**New Free Lift Cylinder**
Number of Part	37	28
Estimated labor (sec)	964	734
DFA Index	8.7	12.7

2.6 A SHORT CASE STUDY 3: MOTOR DRIVE ASSEMBLY

(Source: Boothroyd *et al*., 1994)

2.6.1 Situation

Figure 2.5 shows the requirements of a motor drive assembly that must be designed to sense and control its position on two steel guide rails. The principal requirements are a rigid base that is designed to slide up and down the guide rails, and that supports the motor and sensor.

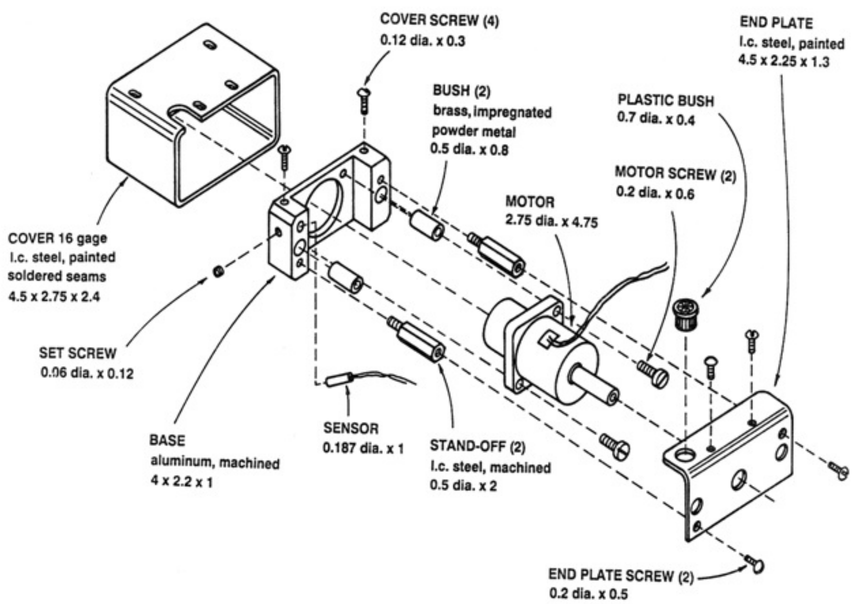

Figure 2.5: Initial design of motor-drive assembly
(Source: Boothroyd *et al*., 1994)

A proposed solution is shown in Figure 2.6. The base is provided with two bushes to provide suitable friction and wear characteristics. The motor is secured to the base with two motor screws, and a hole in the base accepts the cylindrical sensor, which is held in place with a set screw.

To provide the required covers, an end plate is secured by two end-plate screws to two standoffs, which are, in turn, screwed into the base. This end plate is fitted with a plastic bush through which the connecting wires pass. Finally, a box-shaped cover slides over the whole assembly from below the base, and is held in place by four cover screws, two passing into the base, and two into the end cover.

Two subassemblies are required, the motor and the sensor, and, in this initial design, there are eight additional main parts, and nine screws, making a total of 19 items to be assembled.

2.6.2 DFA Analysis

From this analysis, it can be seen that, if the motor and sensor subassemblies can be arranged to snap or screw into the base, and a plastic cover can be designed to snap on, only four separate items will be needed, instead of 19. These four items represent the theoretical minimum number needed to satisfy the constraints of the product design without consideration of the practical limitations.

In this example, it can be argued that two motor screws are needed to secure the motor, and one set screw is needed to hold the sensor, because any alternatives would be impractical for a low volume product such as this. It can be argued that the two powder metal bushes are unnecessary, because the base could be machined from an alternative material with the necessary frictional characteristics.

2.6.3 DFA Result

Using DFMA time standards and knowledge bases, it is possible to make estimates of assembly costs, and then to estimate the cost of the parts and associated tooling, without having final detail drawings of the parts. First, Table 2.2 shows the results of the DFA analysis; the total assembly time is estimated to be 160 second. It is also possible to obtain an absolute measure of the quality of the design for ease of assembly.

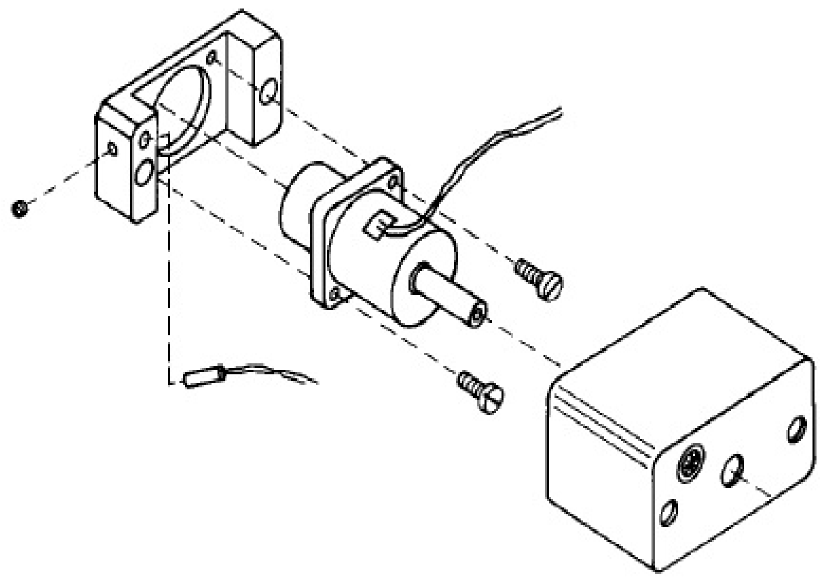

Figure 2.6: Proposed design
(Source: Boothroyd *et al*., 1994)

The theoretical minimum number of parts is four, as explained above, and, if these parts were easy to assemble, they would take 3 second each to assemble on average. Thus, the theoretical minimum (or ideal) assembly time is 12 second, a figure which can be compared with the estimated time of 160 s, giving an assembly efficiency (or DFA index) of 12/160, or 7.5 percent.

2.6.4 Redesign Concept

Here Figure 2.7 is come out with the bushes are combined with the base, and the standoffs, end plate, cover, plastic bush and six associated screws are replaced by one snap-on plastic cover.

Table 2.2: Results of DFA analysis for initial design of motor drive assembly.
(Source: Boothroyd *et al*., 1994)

Items	**Number**	**Theoretical part count**	**Assembly time (s)**
Base	1	1	3.5
Bush	2	0	12.3
Motor Subassembly	1	1	9.5
Motor screw	2	0	21.0
Sensor subassembly	1	1	8.5
Sensor screw	1	0	10.6
Stand off	2	0	16.0
End plate	1	1	8.4
End plate screw	2	0	16.6
Plastic bush	1	0	8.5
Thread lead	-	-	5.0
Reorient	-	-	4.5
Cover	1	0	9.4
Cover screw	4	0	31.2
Total	19	4	160.0

[Design efficiency =4 x 3/160=7.5%.]

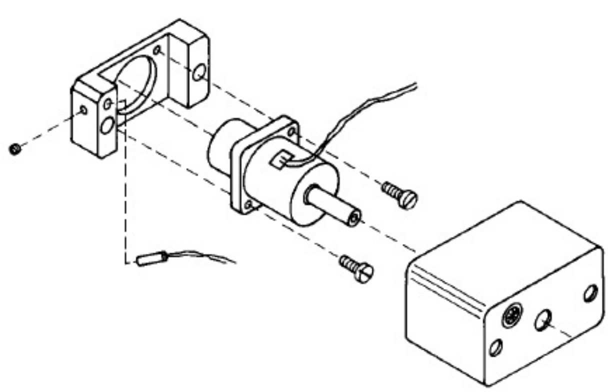

Figure 2.7: Redesign of motor-drive assembly
(Source: Boothroyd *et al*., 1994)